ERROR PROPAGATION IN FAST FIELD-CYCLING RELAXOMETRY

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Background

Fast field-cycling (FFC) methods differ from those of conventional nuclear magnetic resonance, in that the main magnetic field strength (B_0) is rapidly switched higher and lower during the course of an experiment[1]. FFC is the dominant approach to studying the variation in relaxation times with measurement frequency; variation which may be linked rather directly to physical properties such as porosity or protein concentration[2,3], and therefore forms a rich source of potential biomarkers.

While quality assurance is well established in MRI, no equivalent consensus has been achieved in MR field-cycling relaxometry, despite the relevance of quality to increasingly critical applications in industry and research (including biomedicine). In previous work, we identified additional sources of error to be controlled by quality control checks[4]. In this abstract, an error propagation analysis for localised T_1 relaxometry[5] is presented and its implications for QA discussed.

Methods

In the model of [5], T_1 is calculated from two acquired signals S_I and S_{NI} (with and without a preparatory inversion pulse respectively). The uncertainty in T_1 as a function of the signals is:

$$\sigma_{T_1} = \sqrt{\left(\frac{\partial T_1}{\partial S^{NI}}\sigma_{S^{NI}}\right)^2 + \left(\frac{\partial T_1}{\partial S^{I}}\sigma_{S^{I}}\right)^2}$$
$$= \sigma_s\sqrt{\left(\frac{\partial T_1}{\partial S^{NI}}\right)^2 + \left(\frac{\partial T_1}{\partial S^{I}}\right)^2}.$$

Using the Symbolic Toolbox of software package MATLAB, the partial differentiation reveals that:

$$\sigma_{T_1} = \sigma_s V,$$

where V includes terms dependent on experimental parameters, the mean signal values, and T_1 at the field strengths of interest and of acquisition.

Results and Discussion

When measured using a sequence for localised field-cycling relaxometry, the uncertainty in T_1 is directly proportional to the noise in the bandwidth of the acquired signal σ_s. With this relationship known, it is straight forward to calculate the maximum instrumental variance tolerable from the required measurement precision (which is necessarily application-specific, e.g. of the order of 5% for osteoarthritis characterisation[6]).

The error propagation analysis described above may assist in the setting of SNR action levels when field-cycling relaxometry is a scanner application. It does not consider other sources of measurement uncertainty, most notably spatial and temporal variations in the RF and static magnetic fields, which should be addressed by other routine tests.

Conclusion

The identified relationship allows measurement uncertainty to be related to instrumental SNR in a field-cycling application. Because other sources of uncertainty exist, any QA regime should include regular phantom measurement of T_1 accuracy/precision over the instrumental field strength range.

References

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